**US Army Corps
of Engineers**
Waterways Experiment
Station

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Demonstration Erosion Control
Project Monitoring Program

Fiscal Year 1992 Report

Volume VI: Appendix E
Expeditious Design and Review
of Pipe-Drop Drainage Features

*by   Chester C. Watson, Steven R. Abt
Colorado State University*

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Prepared for   U.S. Army Engineer District, Vicksburg

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Civil Engineering Department
Engineering Research Center
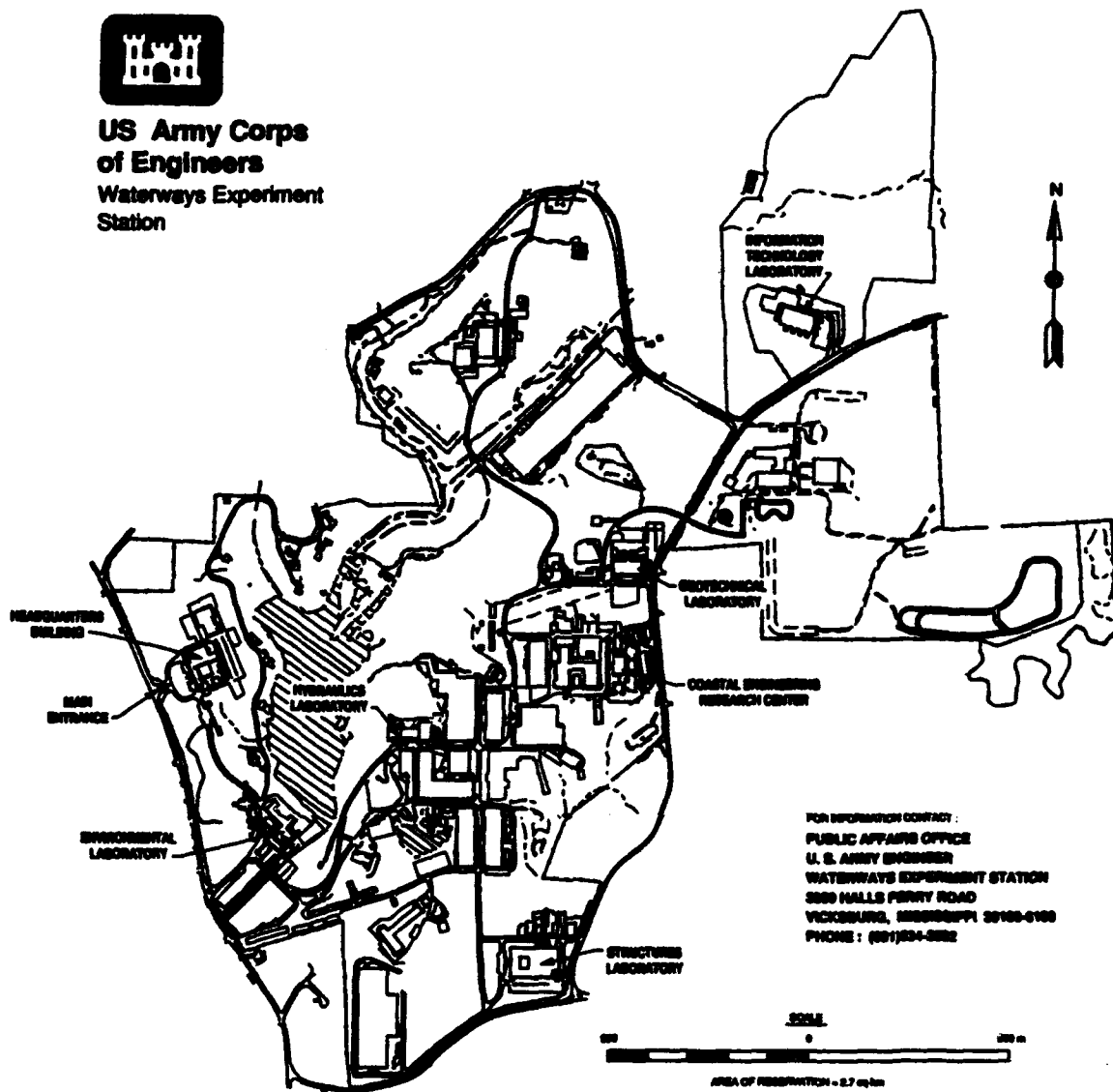Colorado State University
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Final report

US Army Corps
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Waterways Experiment
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Appendix E
Expeditious Design and Review of Pipe-Drop Drainage Features

1.0 INTRODUCTION

Drop pipe drainage features can be valuable components of a comprehensive watershed stabilization plan, and are primarily used in agricultural watersheds to provide a non-eroding drainage inlet from upper bank drainage to the channel bottom. In the Yazoo Basin, many of the streams are severely incised and relatively minor amounts of upper bank drainage can result in gully formation and advancement. Used in this situation, the drop pipe can save significant agricultural production loss and can reduce soil loss into the channels.

1.1 Purpose

The purpose of this project has been to develop a procedure for the design of pipe drop structures that will reduce the overall cost of hydraulic engineering and design for these features. Both the hydraulic and hydrology aspects of the design process have been examined and modifications in the design process have been recommended.

1.2 Report Organization

Chapter 2 of this report includes a discussion of the applicability of types of drop or grade control structures, and a discussion of the recommended uses of the drop pipe. Chapter 3 begins with a discussion of the U.S. Department of Agriculture, Soil Conservation Service (SCS) hydrology programs EFM2 and TR-55, which have been the basis for the existing hydrology design procedure. The hydraulic program DR-PIPE has been developed by personnel of the Vicksburg District, COE based on SCS guidelines, and these guidelines will also be presented. Chapter 4 includes a discussion of alternative methods

for development of project hydrology and hydraulics and some additional recommendations.

1.3 Authorization

This research was conducted under authorization of Contract No. DACW39-91-C-0077 between the U.S. Army Engineer Waterways Experiment Station (WES) and Colorado State University (CSU). Mr. Nolan K. Raphelt was the Technical Program Officer for the contract. Principal Investigators for the project were Dr. Chester C. Watson, Research Assistant Professor, and Dr. Steven R. Abt, Professor, Civil Engineering Department at Colorado State University.

1.4 Acknowledgement

This project was completed with the assistance of personnel of the U.S. Army Engineer Waterways Experiment Station, in particular, Mr. Mike Trawle, Mr. Nolan Raphelt, Ms. Brenda Martin, and Dr. Bobby Brown. Mr. John Smith and Mr. Charles Little of the Vicksburg District were of special value in furnishing data and discussing the design procedures. Ms. Helen Fox Moody of the SCS Technology Development and Support Staff graciously provided SCS literature and computer programs. Others in these agencies provided valuable assistance. The help of all who assisted us in this research is gratefully acknowledged.

2.0 DROP PIPE STRUCTURES

Drop pipe structures belong to a family of structures generally referred to as grade control structures. The primary purpose of these structures is to provide a positive base level for the upstream channel. In addition to this primary function, grade control structures can be used to provide storage of water and sediment, and can be used, with the proper instrumentation, for stream discharge measurement sites. The SCS (1984) terminology for spillways can be applied to most types of drop structures. That terminology describes structure components as the earth embankment, inlet, conduit, and outlet. The three principal types of structures used by the SCS are the drop spillway, the drop inlet spillway, and chute spillways. Figures 2.1 and 2.2 are taken from the SCS (1984) manual and illustrates commonly used types of structures which can be constructed in channels to provide grade control.

Various combinations of inlets, conduits and outlets can be combined for specific applications. For example, this report primarily is concerned with pipe drop structures, in which the drop inlet spillway shown in Figure 2.2 uses corrugated metal pipe for the inlet, conduit, and outlet.
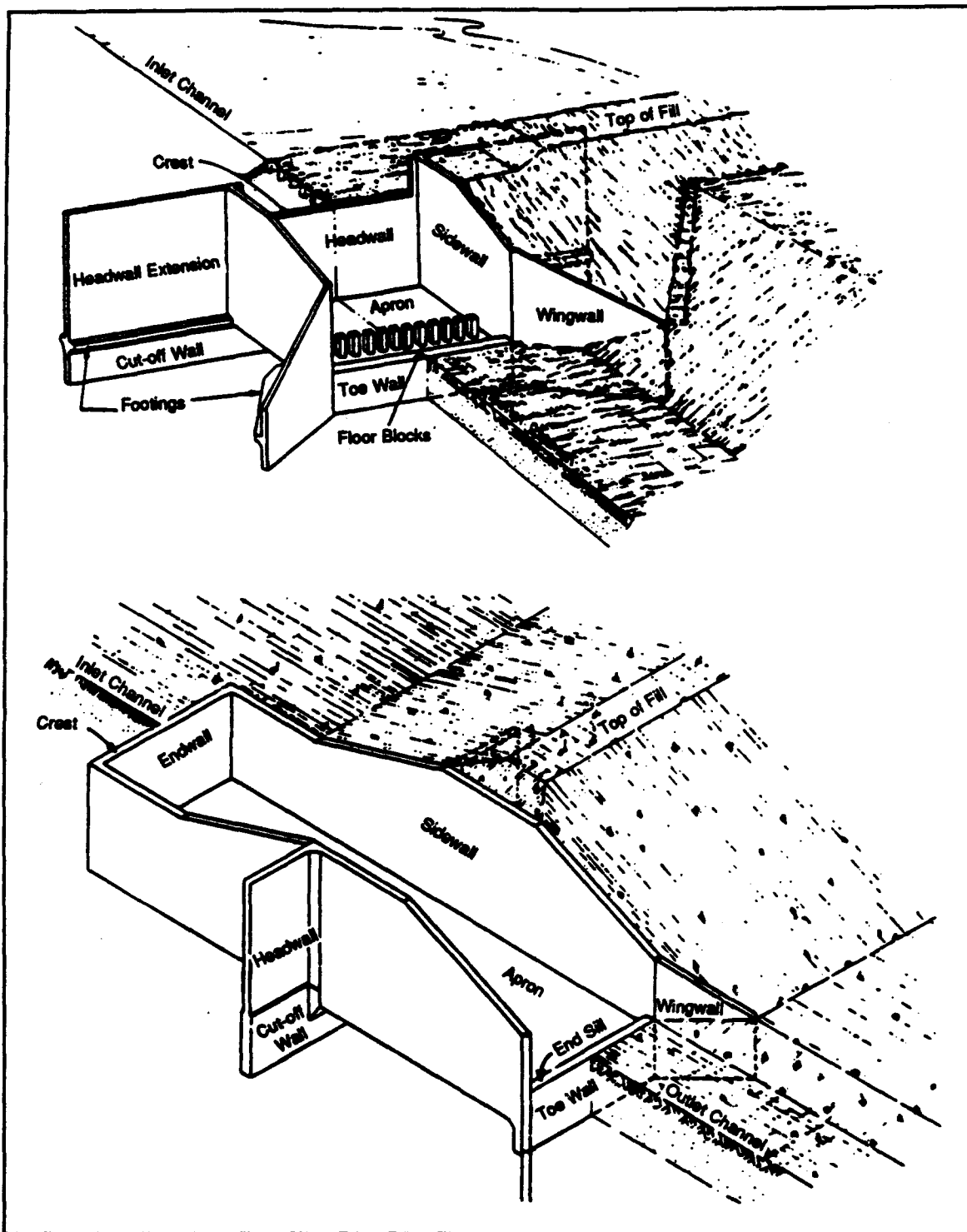
Figure 2.1. Nomenclature for various parts of drop spillways (from SCS, 1984)
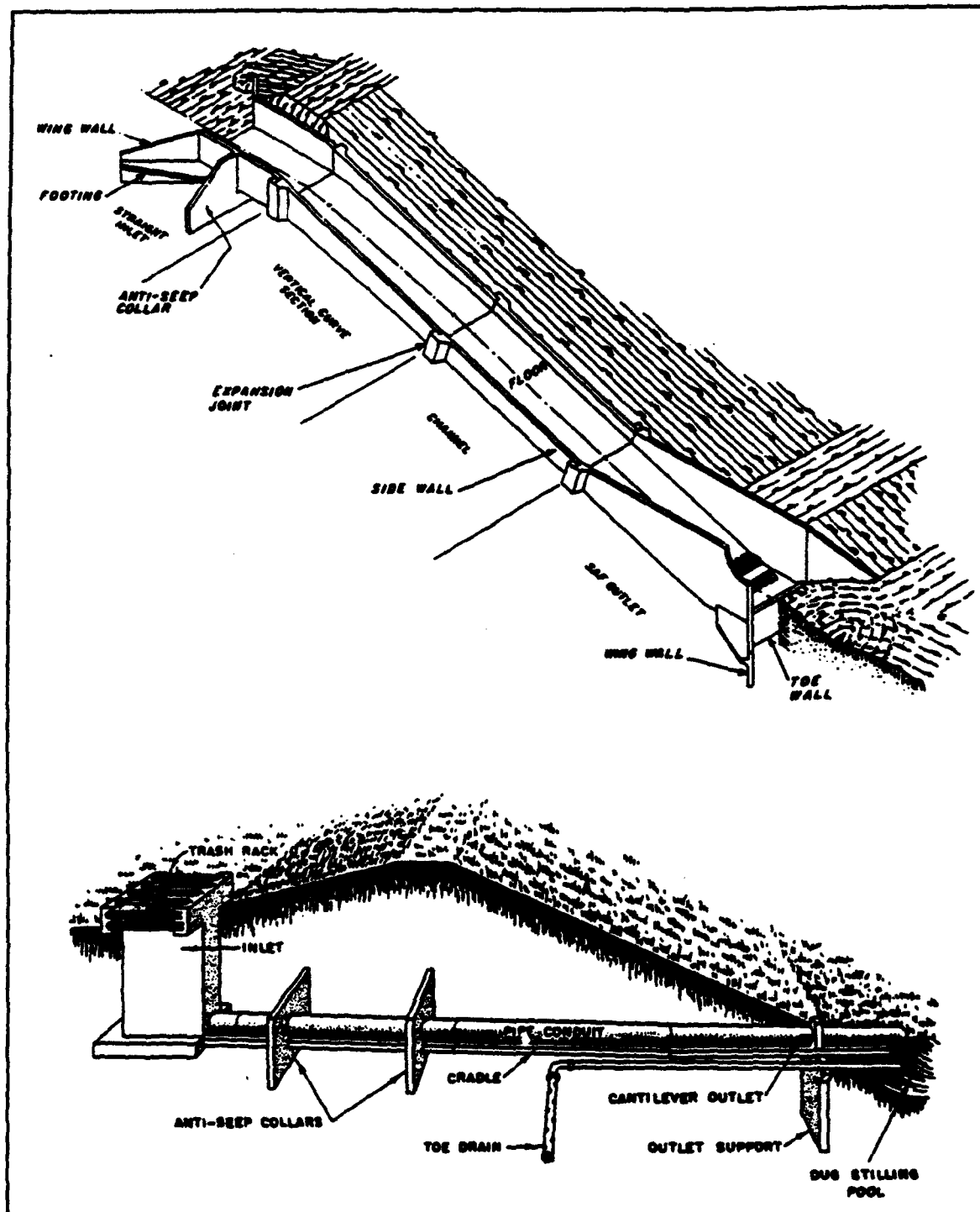
Figure 2.2. Nomenclature for various parts of chute and drop inlet spillways (from SCS, 1984)

Embankments are used to direct the flow through the structure. If detention of storm flow is an important role of the drop structure, the embankment design and construction may be critical. Many drop structures have been constructed with limited detention, and without the potential for overbank flow. These in-channel structures may have no embankment.

Flow enters the spillway through the inlet, which may be a box, a weir along a wall, or various conduit-type inlets. The box inlet may be straight or flared. The wall may be straight, flared, or curved. The conduit-type inlet may be round, square, rectangular, and with a square edge, flare, or with anti-vortex modifications.

Vertical walls extending into the soil foundation under the inlet are known as cutoff walls. The main purpose of a cutoff wall is to prevent water seepage under the structure. Similar walls, extending laterally from the inlet to prevent seepage and erosion around the ends of the structure, are called headwall extensions.

Flow in the structure conduit component moves from the inlet to the outlet. The conduit may be closed in the form of a box or pipe, or open as in the form of a rectangular channel. Cutoff walls or anti-seep collars are usually constructed as a part of the conduit to prevent seepage along the conduit length. Seepage can contribute to structure failure.

Flow leaves the structure through the outlet. The primary function of the outlet is to discharge the water into the downstream channel without excessive scour that may destabilize the downstream channel or the structure. The outlet may be cantilevered, a plain apron outlet, or an apron with various types of energy dissipating devices to minimize erosive outlet conditions. (SCS, 1984)

Combination of the various types of components can result is various types of drop structures or spillways. Figure 2.3 is a compilation of data by the SCS (1984) for use as a recommendation for the most economical type of structure for various combinations of discharge and drop height. As shown in the figure, the upper range for discharge is 150 to 200 cfs. This coincides with a drainage area of approximately 80 to 120 acres for a 2-year discharge frequency in the Yazoo Basin. These recommendations are considered to be only general guidelines; however, most of the pipe drop constructed as a result of the DEC program are within this generally recommended range.

		DISCHARGE - C.F.S.								
		10	25	50	100	150	200	400	800	1500
C O N T R O L L E D H E A D (ft)	4	Drop spillways or Hooded inlet spillways				Drop spillways				
	8									
	12	Pipe drop inlet or Hooded inlet spillways							Drop or chute spillways	
	16								Chute spillways	
	20						Monolithic Drop inlet spillways			
	25									
	30									
	40	Pipe drop inlet spillways								
	80									

Figure 2.3. Recommended by SCS (1984) as the most economical type of structure for various conditions of discharge and drop height.

3.0 EXISTING HYDROLOGIC AND HYDRAULIC DESIGN METHODOLOGY

The design hydrology methods presently being used in the Vicksburg District utilize basic SCS Curve Number procedures. Hydraulic calculations for design of the pipe drops use standard hydraulic calculation relationships within a Fortran code developed by personnel of the Vicksburg District. This chapter will present these methods and provide information concerning the theory and limitations of the methods.

3.1 Hydrologic Design Methodologies

The Engineering Field Manual Chapter 2 (SCS, 1989) and Technical Release No. 55 (SCS, 1986) and the companion computer programs are available from the Technology Development and Support Staff of the Soil Conservation Service, U.S.D. A., Washington, D.C.

3.1.1 Engineering Field Manual Chapter 2 (EFM2)

The EFM2 procedure uses the typical SCS curve number procedure for estimation of infiltration and runoff based soil type and land use. Manual planimeter measurement of the drainage area, the area of each land use and each soil type with the drainage area presently requires a considerable effort of perhaps several hours for each drop pipe design. Rainfall is compiled for the drainage area from frequency precipitation tables. The time of concentration is estimated using the following empirical relationship:

$$T_c = L^{0.8}((1000/CN)-9)^{0.7}/(1140\ S^{0.5})$$

where

T_c = time of concentration in hours,
L = flow length in feet,
CN = curve number, and
S = average watershed slope in percent.

For watershed in which significant urban area impacts on the time of concentration, TR-55 methods should be used.

The EFM2 manual states that the average watershed slope can be determined from soil survey data or topographic maps. Published soil survey slope data available within the Yazoo Basin has been generally classified into ranges of slope, for example, 1%, 10%, 15%, and 25%. These general range estimates of soil association slope can then be utilized in the EFM2 program as area weighted slope averages. An alternate approach is to utilize the U.S.G.S. quadrangle maps to compute average slope. Both of these methods may be a source of error in estimating pipe drop runoff: the soil association slope data is only approximate within certain ranges, and the quad sheet topographic data is, at best, based on contour intervals of 5 feet. Data and development of procedures to utilize a 30 meter grid of the best available topographic information within software developed by Intergraph Corporation is presently being tested at WES. Comparison of the new WES procedure with previously utilized manual methods may demonstrate that the new method is more reproducible and accurate.

Worksheets 1 and 2 in the EFM2 manual show the manual steps in the discharge computation. The EFM2 computer program allows a rapid calculation of the hydrology; however, with or without the EFM2 computer program, the laborious task of plainmetering the required areas remains. The EFM2

hydrology procedure includes empirical relationships, and the following limitations are recommended:

* The watershed should have only one main stream.

* The watershed must be hydrologically similar, i.e., able to be represented by a weighted CN. If more that 10% of the area is non-rural, use TR-55.

* Time of concentration should be between 0.1 hour and 10 hours.

* Flow length should be between 200 feet and 26000 feet.

* Snowmelt or rain on frozen ground cannot be estimated with EFM2.

* If potholes comprise more than a third of the area, EFM2 cannot be used.

* Slope must be between 0.5% and 64%.

* The curve number must be between 40 and 98.

3.1.2 Technical Release 55 (TR-55)

Technical Release 55 is an intermediate step between the EFM2 procedure and more thorough procedures such as included in HEC-1. Although TR-55 does contain some empirical relationships, most of the limitations of EFM2 concerning time of concentration, flow length, and slope have been eliminated. TR-55 presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater detention reservoirs. These procedures are applicable in small watersheds, particularly urbanizing watersheds in the United States.

Differences between EFM2 and TR-55 are numerous; however, three fundamental areas of difference are in computation of time of concentration, discharge, and storage effects. The time of concentration is computed by adding the time of travel for segments along the primary watershed flow path. TR-55 includes the capability to compute storm hydrographs whereas EFM2 allows only computation of the peak discharge rate. TR-55 also allows for computation of temporary flood storage, computing either a storage volume required to reduce a peak discharge to a required attenuated flow, or computing an attenuated flow based on a known storage volume.

Technical Release 55 program documentation is thorough and comprehensive. Use of the program allows rapid computation of peak discharge and required storage volumes for desired runoff rates. Data requirements are similar to EFM2. The completion of data input and testing of the WES watershed

data acquisition procedure will enhance the value of the TR-55 program flexibility.

3.2 Hydraulic Design

A microcomputer program, DR-PIPE, was written by the Vicksburg District to compute the head-discharge relationships for the four possible flow conditions of a riser pipe conduit: riser weir flow; riser orifice flow; conduit orifice flow; and conduit flow. The condition that would control is the one which produces the lowest flow for the same headwater elevation or pool level. It is desirable that either riser weir flow or conduit flow control. The discharge relationships for the flow conditions follow:

Riser Weir Flow:

$$Q = 3.2 \ LH^{3/2}$$

> where   L = circumference of riser pipe
>   H = difference in elevation between pool level and crest
>   of the riser.

Riser Orifice Flow:

$$Q = CA \ [2gH]^{1/2}$$

> where   c = pipe orifice coefficient of discharge for short barrel
>   CMP
> $C = [1 + .16 \ D^{0.6} = 1.06/D^{1.2} \ ]^{-1/2} - 0.02D$
>   D = pipe diameter in feet
>   A = area of riser pipe
>   H = difference in elevation between pool level and crest
>   of the riser.

Conduit Orifice Flow:

$$Q = CA \ (2gH)^{1/2}$$

> where   C & A are defined as above except for using conduit
>   diameter
>   H = difference in elevation between pool level and
>   upstream centerline of the conduit.

Conduit Full Pipe Flow:

$$Q = A \ [(2gH) / (1 + Ke + KpL)]^{1/2}$$

> where   A = conduit pipe area
>   Ke = minor losses and entrance loss = 1

Kp = head loss coefficient = $5087 \, D^2/di^{4/3}$
di = pipe diameter in inches
n = Manning's coefficient = .024 for CMP
L = conduit pipe length
H = difference in pool level and tail water elevation
which was assumed to be free flow conditions with
tailwater at pipe invert = 3/4D.

Figure 3.1 is a graph of discharge plotted as a function of water surface elevation using a computer program similar to the DR-PIPE program. The line A-B is for riser weir flow, line A-C is for riser orifice flow, line F-G is for conduit pipe flow, and line E-D is for conduit orifice flow. The vertical line at elevation 100 ft. is the elevation of the emergency spillway. The horizontal line representing a constant 120 cfs is the design discharge. As shown in Figure 3.1, the controlling type of discharge begins at elevation 97 ft., the riser top elevation, and the controlling type of flow continues to be riser weir flow along line A-B until a shift occurs at point y to riser orifice flow. Riser orifice flow results as the head on the riser weir continues to build until the plunging nappe becomes completely submerged. Controlling flow now moves along line A-C, the riser orifice flow condition from point y to point z. At water surface elevations greater than point z, the controlling type of flow is along line F-G, conduit pipe flow. The Bureau of Reclamation (1974) refers to flow conditions in the range of x,y, and z as an erratic flow condition in which the type of flow and the capacity or water surface elevation could shift erratically between the three computed elevation-discharge relationships. Erratic flow conditions can result in damage to the structure.

Figure 3.2 shows the same elevation-discharge relationships, except the riser diameter has been increased to the next larger commercially available pipe size. This change in pipe size shifts line A-B up and to the left, resulting in the riser weir flow line to intersect a 100 cfs discharge at approximately 98.7 ft. and the conduit pipe flow line (F-G) to intersect A-B at approximately 98.9 ft. The change allows the controlling flow to shift directly from riser weir flow to conduit pipe flow, and thus, eliminates the erratic x-y-z range. Figure 3.2 represents a satisfactory hydraulic design in which orifice flow is not present and design capacity of 120 cfs is available at or below the emergency spillway elevation.

Table 3.1 illustrates a characteristic of drop pipe design, i.e., that combinations of design parameters are suitable for a range of discharges, not a single discharge. Designs A and B are hypothetical configurations of spillway, thalweg, riser pipe, and conduit exit elevations that are within the ranges expected in DEC application of these structures. For Design A the average satisfactory discharge range is about 18 cfs, and for Design B the satisfactory discharge range is about 45 cfs. These ranges result because manufactured pipe diameters are generally available only in 6-inch increments, and the amount of flow allowable in a given size pipe is a function of head available.
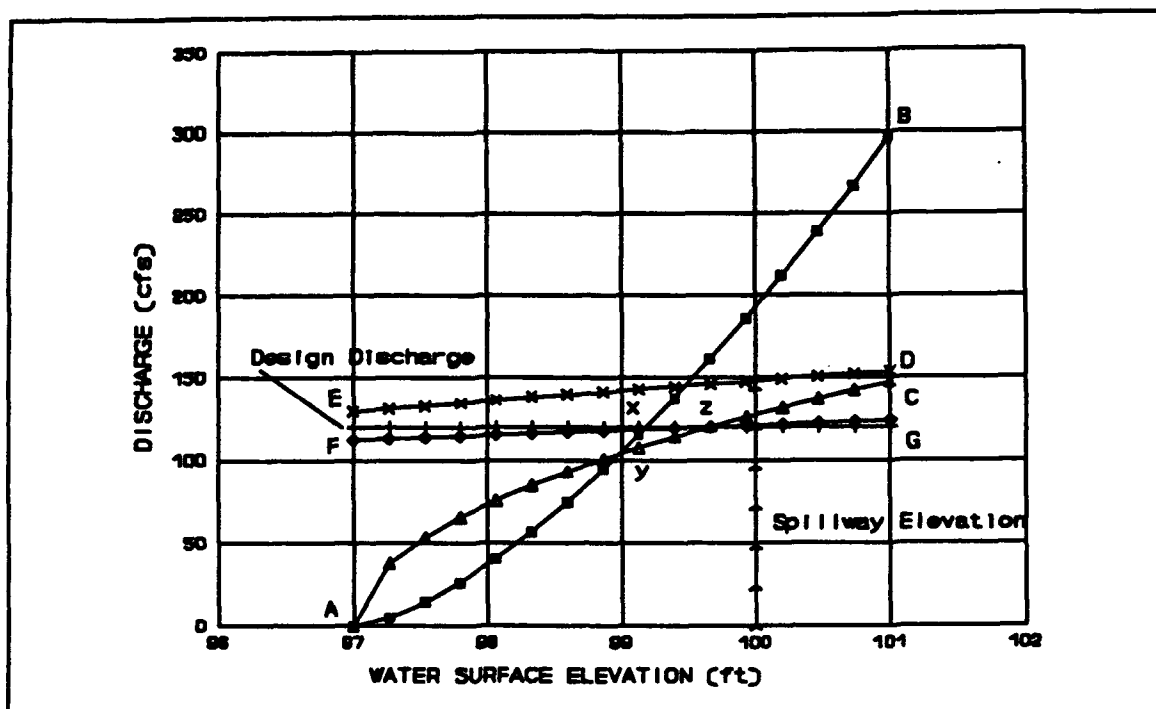
Figure 3.1 Discharge rating curves showing the erratic flow zone (x-y-z)
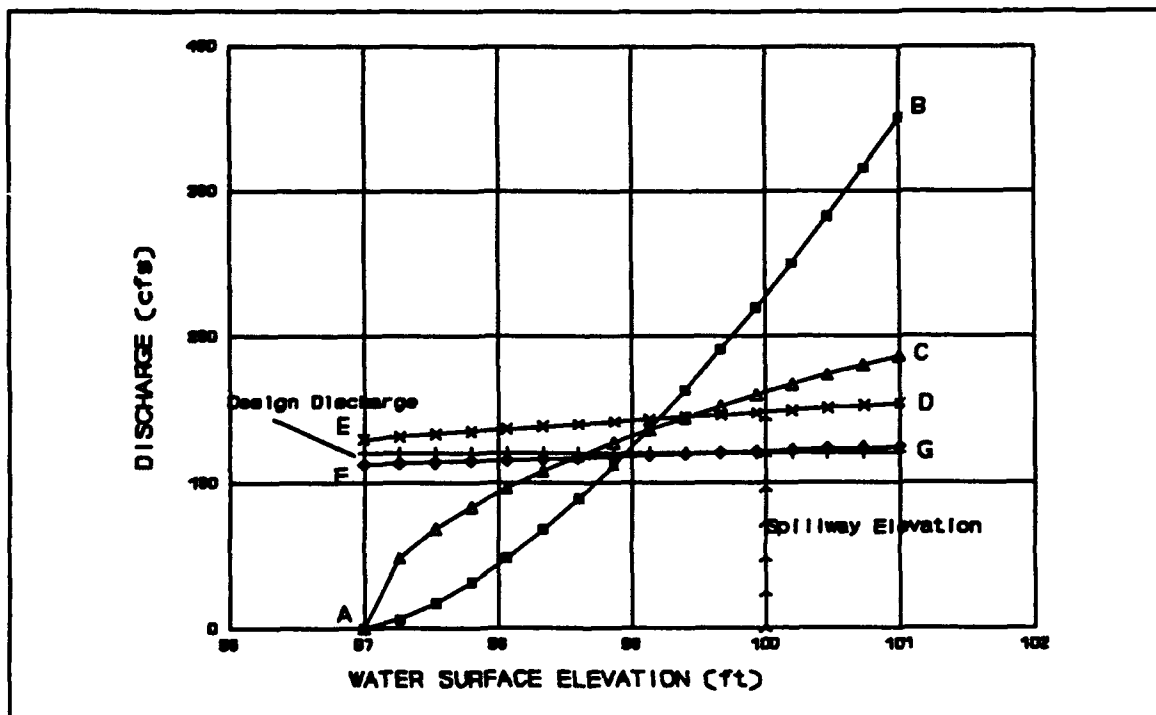
Figure 3.2 Discharge rating curves for a properly sized pipe drop

Table 3.1
Discharge Ranges for Two Typical Designs

	Lower Range (cfs)	Upper Range (cfs)	Riser, Conduit Diam. (inches)
Design A	0	32	30,24
	34	44	36,24
	45	76	42,30
	77	110	48,36
	112	118	54,36
	120	123	54,42
	124	137	60,42
	138	151	66,42
	152	165	72,42
Design B	0	40	30,24
	42	70	42,30
	72	108	48,36
	110	154	54,42
	156	208	60,48
	208	271	72,54

4.0 RESULTS AND RECOMMENDATIONS

The stated purpose of this research has been to develop design procedures that would reduce the overall cost of hydraulic engineering and design for drop pipe drainage features. This chapter includes a discussion of hydrology and hydraulic design procedure alternatives which may be applicable, and includes recommendations resulting from the development of those modifications.

4.1   Results

The primary results of the research are: a) development of a regression of hydrologic data that, for similar conditions, can quickly predict design discharge based only on drainage area, and b) development of Lotus 1-2-3 spreadsheets for hydrologic and hydraulic design programs that can be used in the office on desk model IBM-Compatible computers or in the field on the HP-95LX palm top calculator.

4.1.1   Regression of Hydrologic Data

A set of pipe drop design hydrology and hydraulics calculations were furnished by the Vicksburg District. These calculations were made using standard U.S. Army Corps of Engineers and SCS design procedures, and were the work product of an A-E Contractor. The work is considered to be satisfactory set of calculations, and has been used as a baseline for comparison. Table 4.1 is a listing of the contractor derived data used in the comparison.

A comparison was first made to determine the correlation between the contractor computed 2-year discharge and the discharge computed by the SCS EFM2 program. Figure 4.1 illustrates a close correlation with a correlation coefficient near 0.99. Figures 4.2 through 4.5 illustrate the correlation between a selected variable and the EFM2 computed discharge. Correlation with the curve number, time of concentration, and slope are poor; correlation with watershed length is somewhat improved. Figure 4.6 illustrates the correlation between drainage area and EFM2 computed discharge, which yields a correlation coefficient of 0.95.

$$Q_{2\text{-yr.}} = 3.41(\text{Drainage Area})^{0.86}$$

This figure portrays the strength of a simple power function between the drainage area and the discharge for forty-nine DEC watersheds.

Figure 4.7 illustrates the comparison between the EFM2 computed discharges and the discharges computed from the regression. The following statistics define the relationship between the EFM2-, the contractor-, and the regression-computed discharges. The EFM2 method was used as the standard, and the differences between the EFM2 and the regression discharges were

Table 4.1
Contractor Data Set

| SITE NUMBER | AVERAGE SLOPE | CURVE NUMBER | BASIN LENGTH | TIME OF CONC | AREA | DISCHARGE | | | RISER DIA | CONDUIT DIA |
| | | | | | | 2-YR | 5-YR | 10-YR | | |
	(%)		(ft)	(hr)	(acres)	(cfs)	(cfs)	(cfs)	(in)	(in)
BFC-S1	3	81	940	0.282	16.1	39.0	53.0	68.0	48	24
BFC-S2	1	88	560	0.253	7.0	22.0	30.0	35.6	36	24
BFC-S3	2	85	1000	0.317	16.3	45.0	58.0	72.0	36	30
BFC-S4	13	75	1190	0.196	15.9	38.0	56.0	73.0	36	24
BFC-S5	4	82	1500	0.344	10.6	31.8	43.2	54.0	36	24
BFC-S6	2	88	1500	0.394	26.9	73.0	98.0	120.0	60	36
BFC-S7	1	61	950	0.858	10.1	5.4	9.0	13.0	36	24
BTB-39	18	80	4257	0.398	179.4	355.0	490.0	625.0	54	42
BTB-40	2	72	870	0.423	11.4	16.0	23.0	31.0	24	24
BTB-41	11	81	2410	0.313	46.6	120.0	163.0	206.0	42	36
BTB-42	10	84	2670	0.322	77.8	195.0	266.0	330.0	42	36
BTB-43	12	75	1770	0.280	20.1	45.0	66.0	82.0	36	30
BTB-44	7	80	2350	0.397	48.6	105.0	140.0	178.0	48	36
BTB-45	16	79	8340	0.745	300.6	472.0	667.0	818.0	54	42
BTB-46	2	86	1140	0.340	10.1	30.0	42.0	48.0	36	24
BTB-48	25	73	2440	0.266	91.3	168.0	235.0	295.0	60	48
CWD-10	1	86	1110	0.471	13.4	30.6	40.0	47.0	30	24
CWD-11	7	79	3080	0.508	35.6	72.0	100.0	122.0	48	36
CWD-13	1	88	1250	0.481	12.4	32.8	41.8	48.8	42	24
CWD-2	7	82	3450	0.506	87.1	170.0	230.0	275.0	60	48
CWD-3	2	86	930	0.289	11.1	32.0	41.0	48.0	30	24
CWD-4	7	85	3120	0.422	83.5	190.0	245.0	295.0	66	48
CWD-5	3	88	850	0.204	8.0	28.0	36.0	42.0	48	24
CWD-7	1	86	1390	0.564	16.3	36.0	47.0	56.2	36	24
CWM-1	3	87	3280	0.624	118.1	215	275	325	60	42
CWM-10	10	83	3460	0.410	113.5	240	320	380	54	42
CWM-11	1	88	1230	0.475	10.4	28.2	36.2	42.8	54	24
CWM-12	4	85	1660	0.337	17.5	51	67	80	60	30
CWM-13	14	75	4620	0.559	190.9	235	335	425	54	42
CWM-14	10	83	2550	0.321	54.1	135	186	215	60	42
CWM-15	13	79	1780	0.240	27.1	67	92	110	42	30
CWM-17	11	82	2190	0.280	49.0	125	165	195	42	30
CWM-19	1	88	1520	0.562	21.0	48.8	60.8	71.6	60	30
CWM-21	15	78	2480	0.301	41.3	95	128	155	48	36
CWM-22	10	78	3480	0.483	112.0	185	250	290	72	54
CWM-23	1	85	1430	0.598	22.1	42	55	64	36	30
CWM-24	1	87	1320	0.522	13.2	32.6	41.6	49.6	48	24
CWM-3	5	84	4980	0.751	190.1	285	385	450	72	42
CWM-5	7	78	2650	0.464	52.5	92	125	160	72	36
CWM-7	10	79	1960	0.296	27.2	65	88	105	42	36
CWM-8	7	85	2220	0.321	26.6	76	98	122	48	36
CWM-9	6	79	1290	0.273	27.3	57	79	92	30	24
HTP-12	1	86	2160	0.802	28.8	53.6	73.2	88	30	24
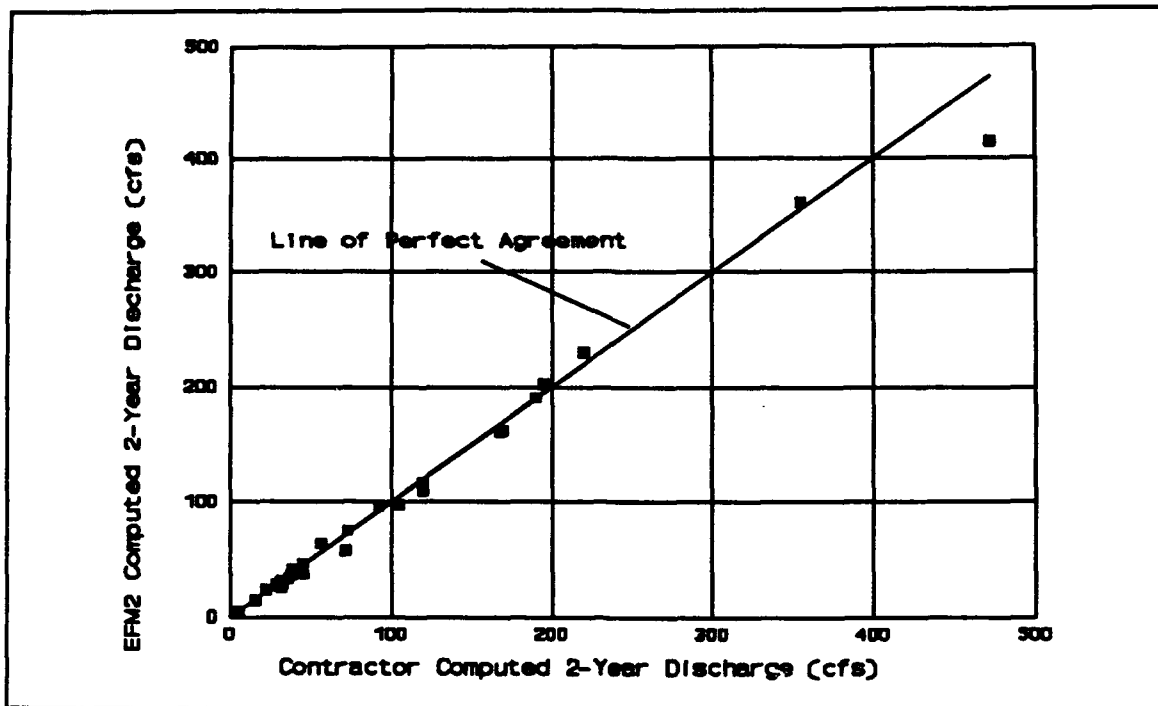
Figure 4.1 Comparison of contractor computed discharge and EFM2 discharge
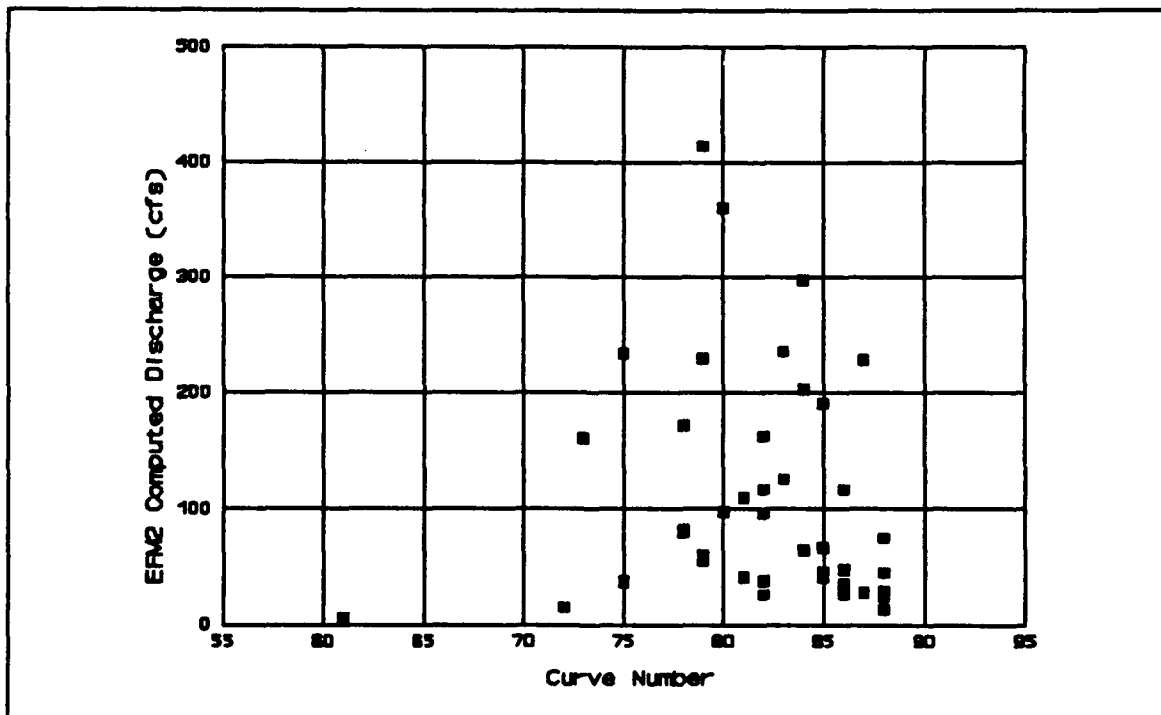

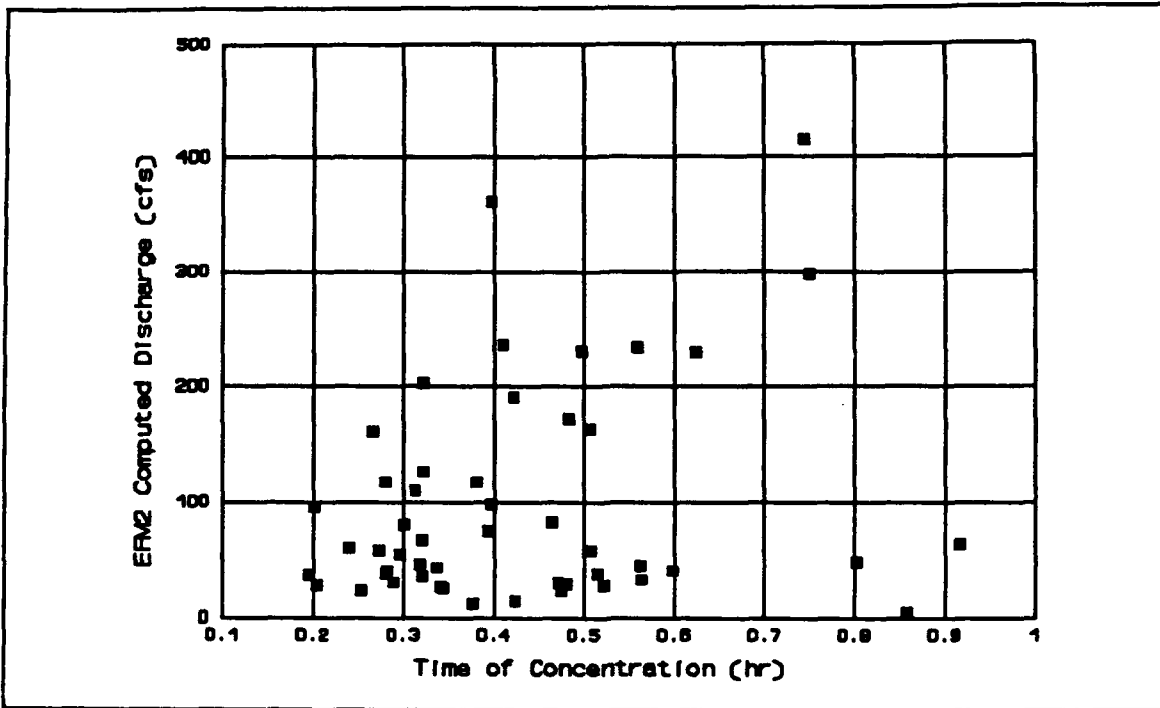**Figure 4.2 EMF2 discharge versus curve number**

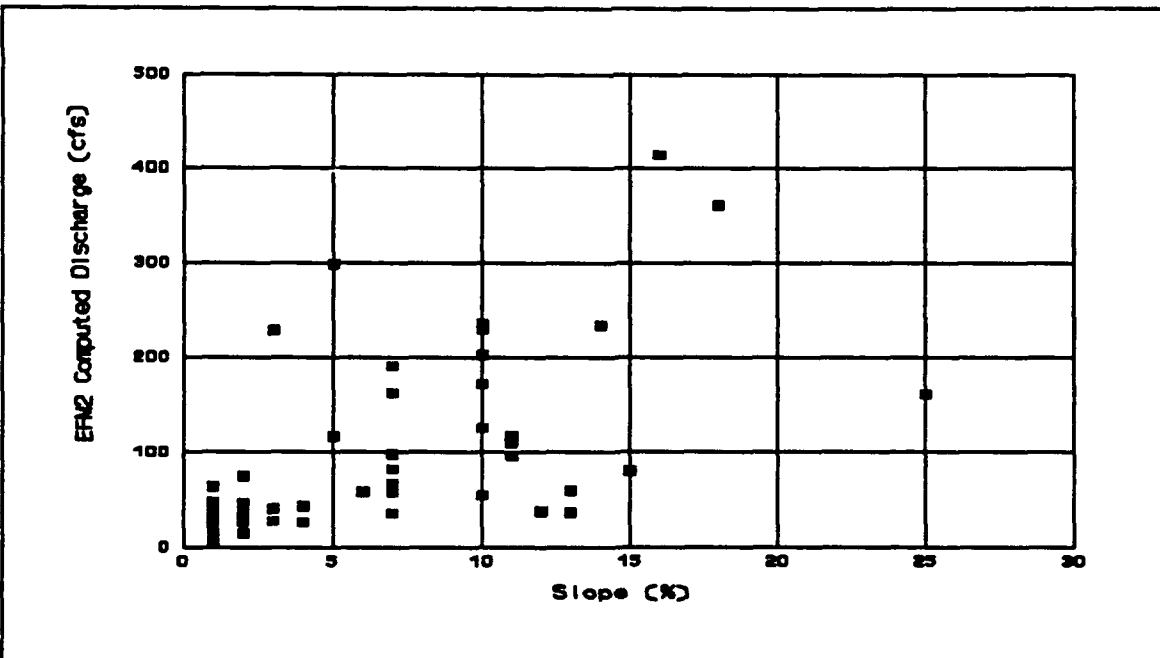Figure 4.3 EFM2 discharge versus time of concentration
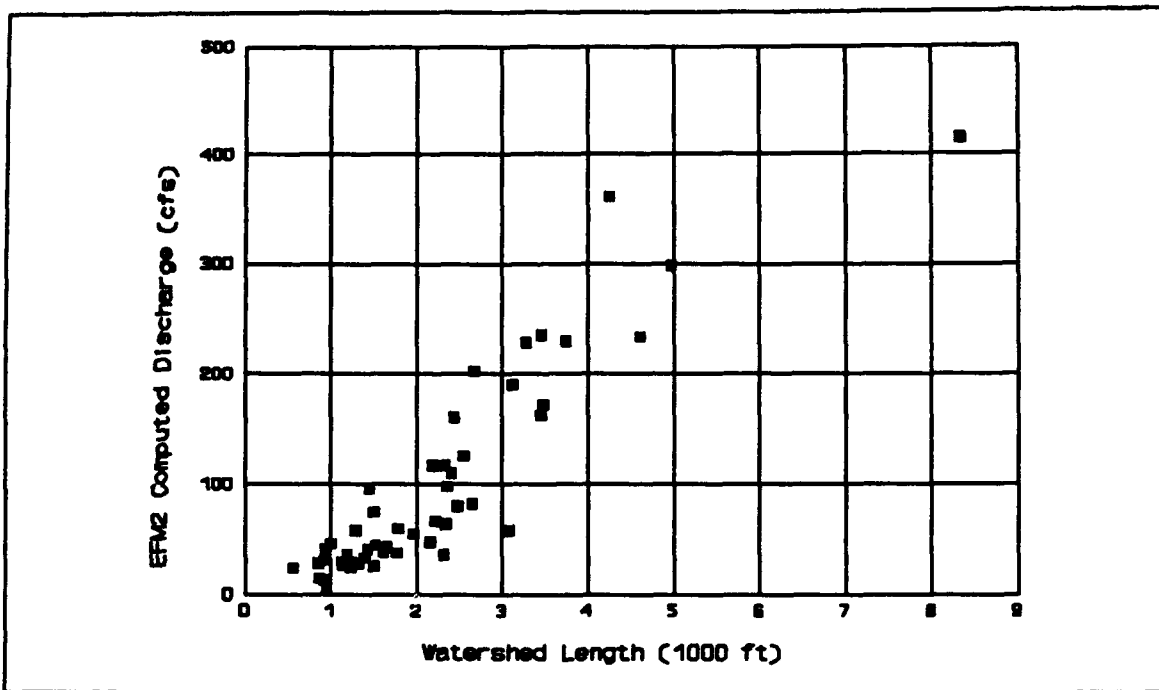

Figure 4.4 EFM2 discharge versus slope
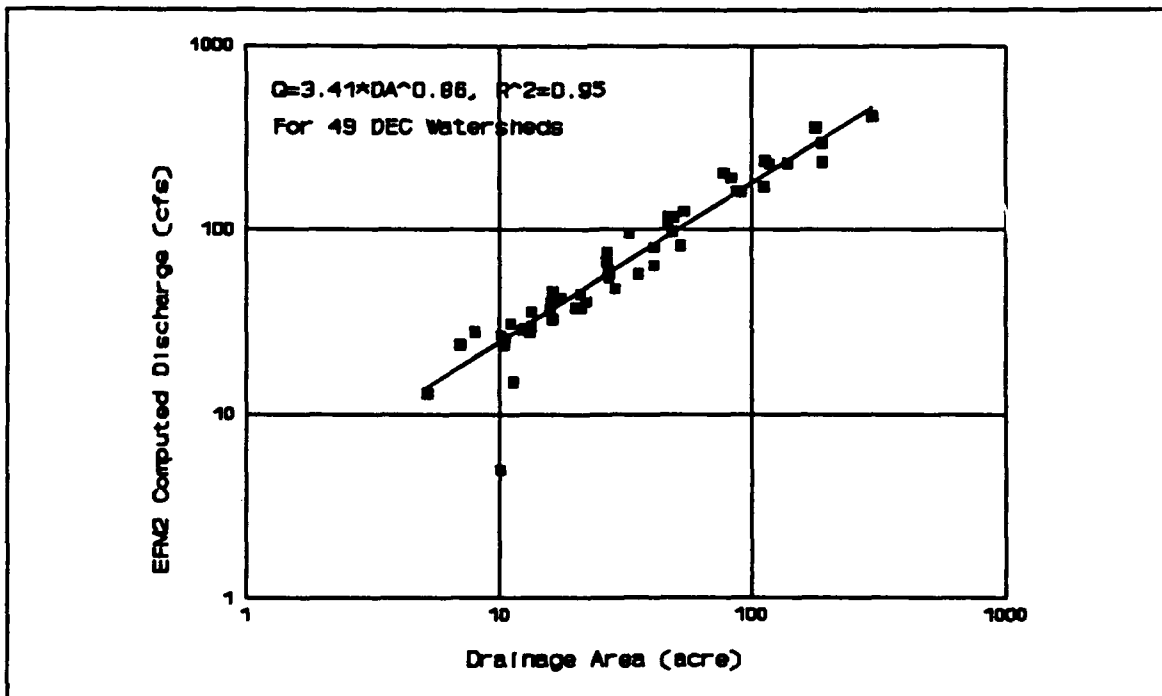
Figure 4.5 EFM2 discharge versus watershed length
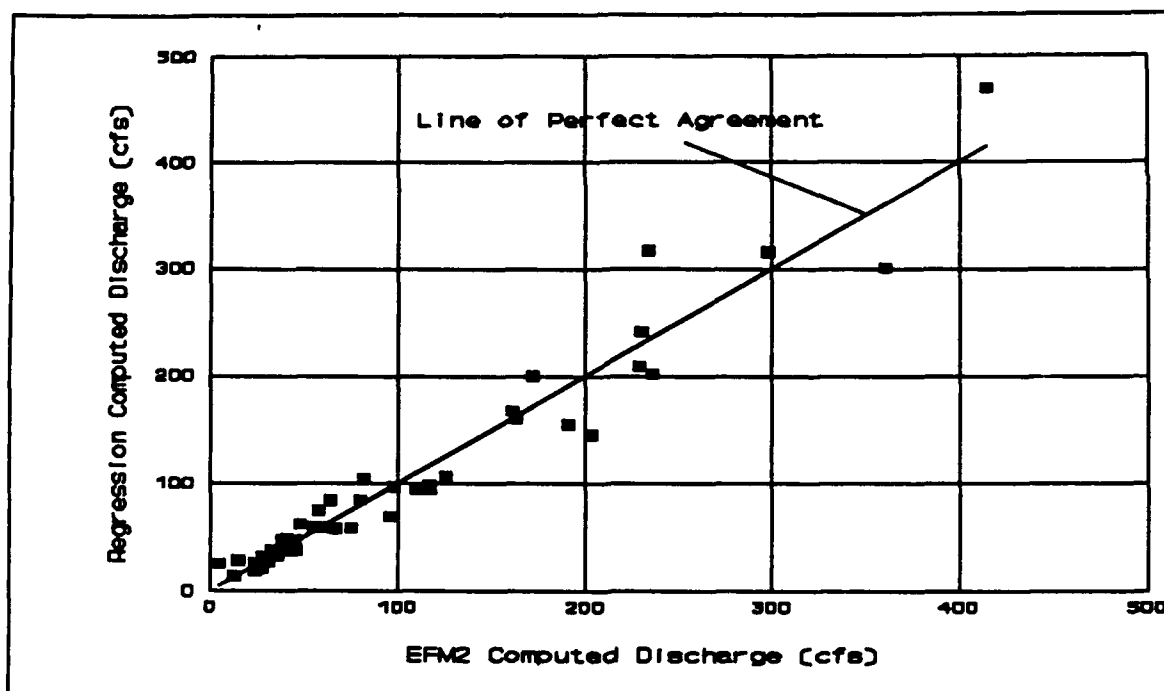

Figure 4.6 EFM2 discharge versus drainage area

Figure 4.7 EFM2 discharge versus regession computed discharge

compared to the differences between the EFM2 and the contractor discharges, as follows:

$$Q_{EFM2} = \text{discharge computed from the EFM2 program,}$$
$$Q_R = \text{discharge computed from the regression,}$$
$$Q_C = \text{discharge computed by the contractor,}$$
$$\% \text{ Diff. } Q_R = (Q_{EFM2}\text{-}Q_R)/Q_{EFM2}, \text{ and}$$
$$\% \text{ Diff. } Q_C = (Q_{EFM2}\text{-}Q_C)/Q_{EFM2}.$$

	% Diff. Q_R	% Diff. Q_C
Average	-1%	-4%
Maximum	+29%	+100%
Minimum	-84%	-26%
Std. Dev.	+20%	+17%

Notice that a negative indicates that the compared methodology over-estimated the EFM2 discharge. The regression procedure average is slightly closer to the EFM2 procedure than the contractor procedure, and the standard deviation of the contractor procedure is slightly lower than the regression procedure. Maximum and minimum values are also shown. In general, the statistics show that the regression method is about as accurate as the contractor procedure for the data set used.

Figures 4.8 through 4.11 are frequency distributions of the data utilized to
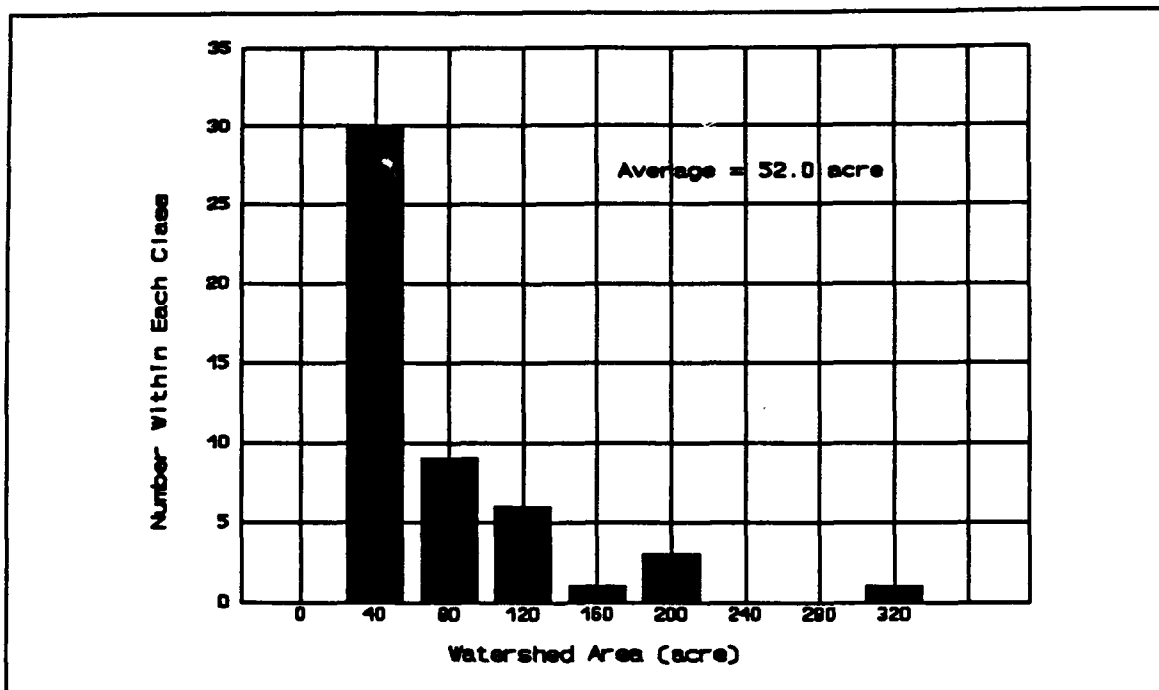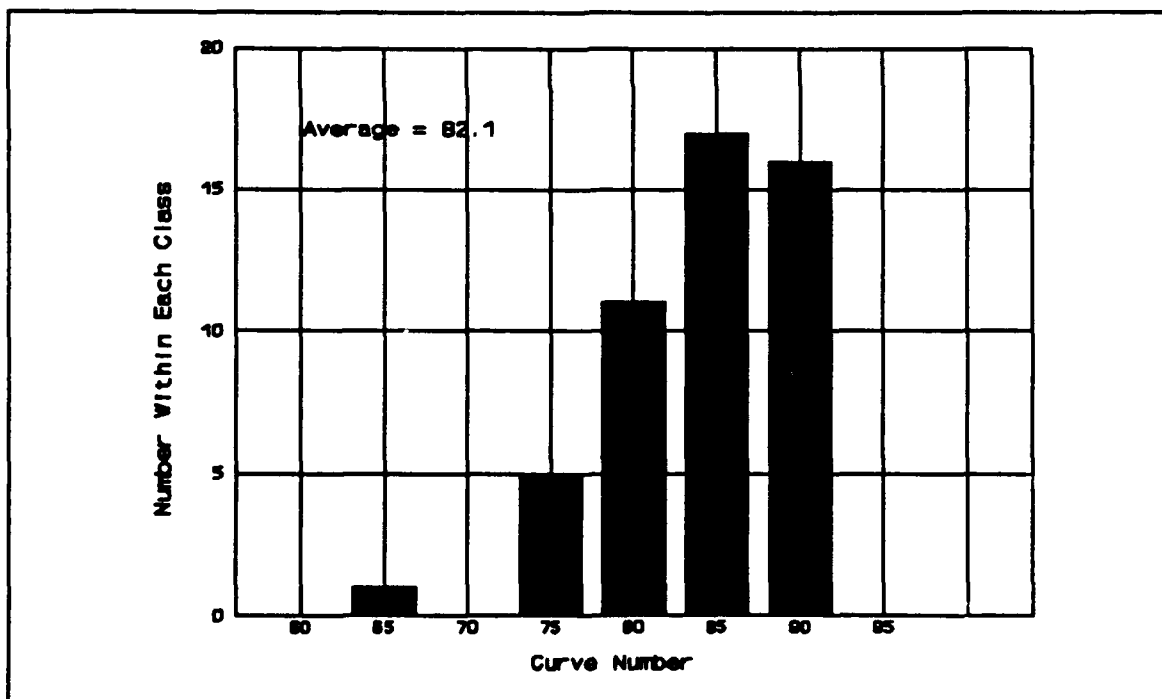
E18

Figure 4.8 Drainage area frequency distribution
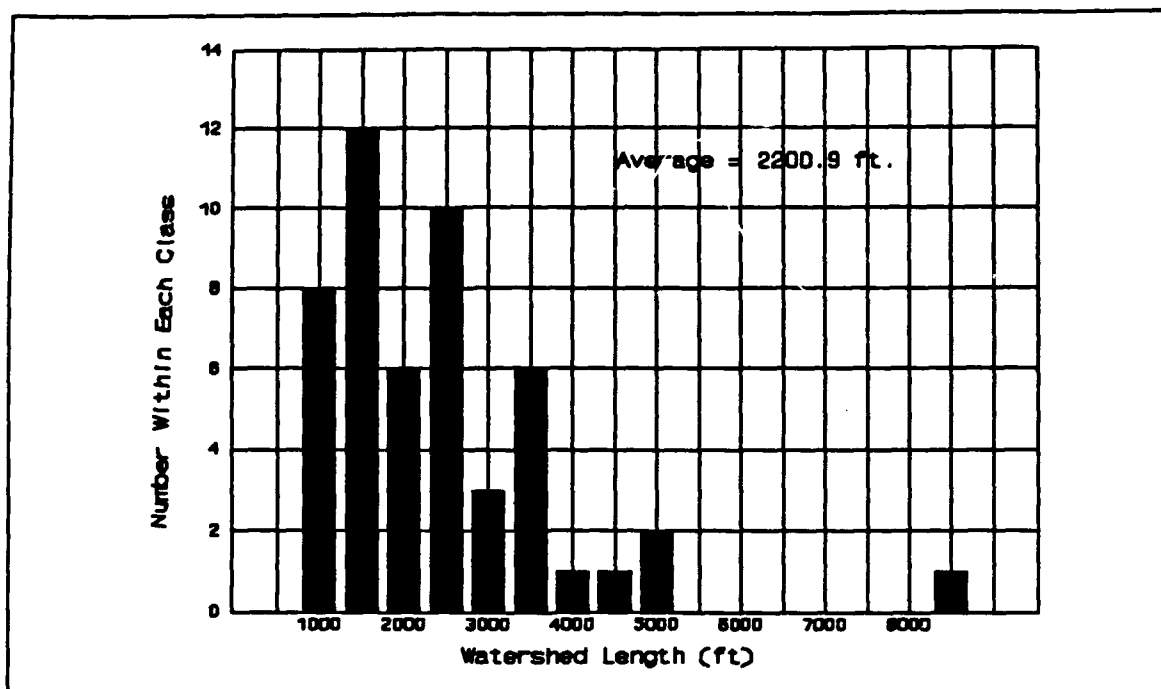

Figure 4.9 Curve number frequency distribution

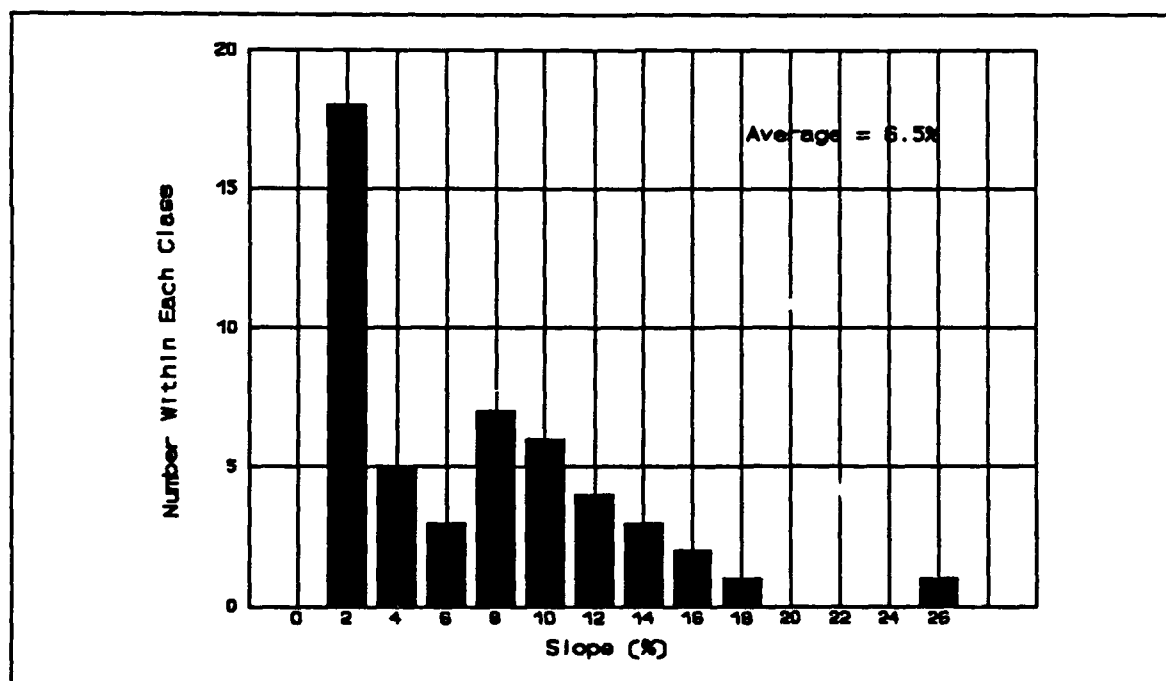**Figure 4.10 Watershed length frequency distribution**

Figure 4.11 Slope frequency distribution

develop the regression. Application of the regression should be limited to the range of data within each of the four parameters. If the range of data of any one parameter is not contained within the graphs, the regression should not be used.

4.1.2 Computational Procedures

As a result of this project, the following procedures were developed:

a. DRPipe, originally developed by the Vicksburg District, computed the size of the riser and conduit pipe for combinations of flow, pipe size, and head over the riser pipe inlet. This program was modified to include a weir coefficient that varies as a function of the ratio of the head over the weir crest and the radius of the riser pipe. The modification is based on physical model studies by the Bureau of Reclamation (1974) on "glory hole" type spillways. A recommendation is made to test this modification using the typical drop pipe entrance. This program was developed in Fortran.

b. PDROP is a Lotus spreadsheet program developed as an alternative to the DRPipe program. Lotus was used because of the ease in data entry, better graphics display, and the convenience of the HP 95LX Palmtop computer. The Palmtop is 6.3"x3.4"x1" and weighs only 11 ounces. In addition, the spreadsheet is available for use on laptop or desktop PC devices.

c. REGRESS is the simple regression of drainage area and 2-yr. discharge data that may be useful in quickly estimating drop pipe discharge. REGRESS is available on both the Palmtop and the PC devices in spreadsheet form.

d. EFM123 is a spreadsheet version of EFM2, incorporating the same relationships as developed by the SCS. The primary difference is that the 2-yr. precipitation must be given as input data whereas in the SCS program, the precipitation can be read from a file for each county in Mississippi. The program is available on the Palmtop and on the PC.

Two versions of PDROP are included with this report, PDROP is a full version of the program with documentation included on the spreadsheet and PDROPP is a simplified version with portions of the program protected against accidental change. EFM123 is the full documented version, EFMP is the protected version. REGRESS and REGRESP are also given. Figure 4.12 is the data input and calculation portions of the PDROP spreadsheet and the graphs shown as Figures 3.1 and 3.2 were developed using PDROP. Figure 4.13 shows data and result portions of REGRESS and EFM123. In each of these positions of spreadsheets shown, the shaded portion is the data input required.

CSU Drop Pipe Design
Corrugated Metal Pipe

	Project:	DEC
	Stream:	Holopha
	Site:	Hot28

TOP OF DAM	100.5	DAM TOP WIDTH	12.0
SPILLWAY ELEV.	97.5	SIDESLOPE (1 on 7)	2.5
RISER PIPE ELEV.	95.0	DESIGN DISCHARGE	22
THALWEG ELEV.	74.0	NUMBER OF RISERS	1
OUTLET INVERT ELEV. 18	78.0	PIPE DISCHARGE	22.0

Standard Pipe Sizes(18",24",30",36",42",48",54",60",72".)

– RISER MIN IS 30"   38.0 Riser has capacity
                           Riser not in control

– CONDUIT MIN IS 24" 24.0 Conduit has capacity
                           Conduit pipe flow controlling

– Press F10 to review rating curve charts. Riser weir flow or conduit
flow must be below either riser orifice flow or conduit pipe flow.
– Press F8,H,1,ENTER for a table of design values.

DROP PIPE DESIGN PARAMETERS

Project:	DEC
Stream:	Holopha
Site:	Hot28

Thalweg	74.0 ft.	Riser length	18.0 ft.
Top of dam	100.5 ft.	Conduit length	98.8 ft.
Outlet invert	78.0 ft.	Riser dia.	38 in.
Riser top	95.0 ft.	Conduit dia.	24 in.
Riser bottom	78.0 ft.	Q per riser or	22 cfs
Spillway	97.5 ft.	Side slope (1:7)	2.5
No. of risers	1 ea.	Design Discharge	22 cfs

– Type /,P,F, the Site name, ENTER,R,ENTER,ENTER,G,Q to create a file
of the design parameters listed above.

Figure 4.12 Data input and design table from PDROP

```
REGRESSION

DRAINAGE AREA      (acre)              78
DISCHARGE          (cfs)        144.5292




EMF123 – HYDROLOGY
                                Enter
CURVE NUMBER                       65
PRECIPITATION (in)                3.4
BASIN LENGTH (ft)                3400
AREA (acre)                        90
SLOPE (%)                          10
TIME OF CONC (hr)            0.679004
PEAK FLOW (cfs)             32.85139
```

Figure 4.13 REGRESS and EFM123 data input screens

4.2   Recommendations

Use of the PDROP and REGRESS spreadsheets can result in significant reduction in the time required for hydraulic design. The range of applicability and limitations of the REGRESS relationship were discussed in Section 4.1.1 and the user must be aware of the limitations. More confidence in the regression, additional regressions for other watershed conditions, and the usefulness of regressions could be strengthened by developing the statistics on other data sets.

The time required to manually determine slope, land use area, soil type area, and total drainage can be considerably reduced if all the data required are scanned into an Intergraph computer. This will allow the full EFM2 or TR55 hydrology program to be used, thus removing some of the uncertainty introduced using a simple drainage area-discharge regression. This work is underway at WES. Development of the Intergraph procedure will allow rapid comparison of watershed slopes measured from soil association data and topographic mapping.

The total investment in drop pipes in the DEC is considerable. Two additional recommended studies are: a) calibrate a weir coefficient for a range of commercial pipe diameters and for a range in head using prototype

construction including the anti-vortex assembly, and b) monitor a series of 5 or 6 constructed drop pipes by recording inflow and outflow head, and watershed precipitation at several locations. Monitoring could be concentrated on adjacent small watersheds to minimize costs. These recommended studies could prove cost effective in making minor improvements in the design and construction process.

Consideration should be given to using the drop pipe with larger discharge capacity and in different applications than have been used by the Corps of Engineers in the DEC project. The SCS constructed drop road culverts on Beartail Cr. and Hotopha Cr. are examples of larger structures that seem to work well. Perhaps this type of structure could be used with a infrequently over-topped fill to stabilize relatively small streams in the upper watersheds.

Consideration should also be given to a design-construct contract for placement of typical pipe drop structures. Where applicable, the combination of DRPIPE and REGRESS spreadsheets allows rapid computation of pipe size and elevation, and provides a feasible on-site design tool.

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13. ABSTRACT (Maximum 200 words)

The purpose of monitoring the Demonstration Erosion Control (DEC) Project is to evaluate and
document watershed response to the implemented DEC Project. Documentation of watershed responses to DEC
Project features will allow the participating agencies a unique opportunity to determine the effectiveness of
existing design guidance for erosion and flood control in small watersheds. The monitoring program includes 11
technical areas: stream gaging, data collection and data management, hydraulic performance of structures,
channel response, hydrology, upland watersheds, reservoir sedimentation, environmental aspects, bank stability,
design tools, and technology transfer.

The purpose of work described in this Appendix is to develop a procedure for the design of pipe drop
structures that will reduce the overall costs of hydraulic engineering and design for these features. Both the
hydraulic and hydrology aspects of the design process are examined and modifications in the design process are
recommended.

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